Mapping the Physical Properties of Supernova Remnants in our Galaxy

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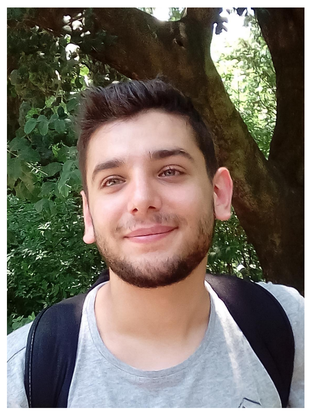

Introduction

The usual approach followed in order to determine the physical conditions of SNRs (eg density, temperature, shock velocity etc.) is to use spectroscopy to measure the intensity of forbidden lines and compare them with predictions from shock excitation models. The use of spectra limits the information only to the area covered by the spectra. In this work, we present a new approach, combining the efficiency of narrow-band imaging with diagnostic grid diagrams which allow us to determine spatially resolved maps of an SNR's physical parameters over its full extent.

Methodology

Our method is based on the translation of $[S_{II}]/H_\alpha$ line ratio maps to shock velocity maps, and it consists of the following steps:

1. Create star-free images based on PSF fitting techniques (Fig. 1).
2. The photometry of the removed stars is used to calculate the scaling of the continuum images and subtract them from the narrow-band ones, producing sky subtracted narrow-band images (Fig. 2).
3. Perform aperture photometry on the narrow-band images of the SNRs (Tab. 1).
4. Divide the $[S_{II}]$ by the H_α image and compare the ratio image with predictions from shock models. Since the H_α narrow-band filter also includes the $[N_{II}]$ lines, we compare against the $[S_{II}]/(H_\alpha+[N_{II}])$ vs shock velocity diagnostic (Fig. 3).
5. Calculate a shock velocity map and the corresponding uncertainties based on the diagnostic (Fig. 4).

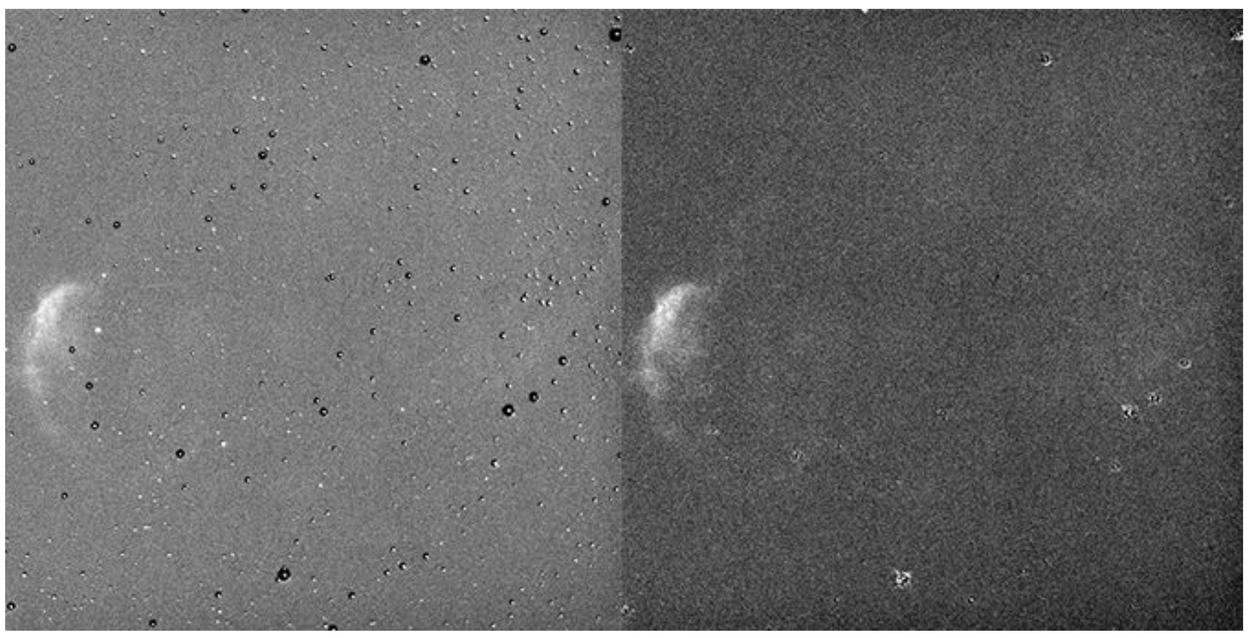

Fig. 1: Continuum Subtraction. When subtracting the continuum, we faced the issue of spatially varying PSF across the image, as well as different PSFs between the narrow-band and broad-band images. This created artifacts in the continuum subtracted from the narrow-band image (left). We overcame the issue by individually fitting and subtracting the stars from the 2 images and then scaling and subtracting the broad- from the narrow-band images (right).

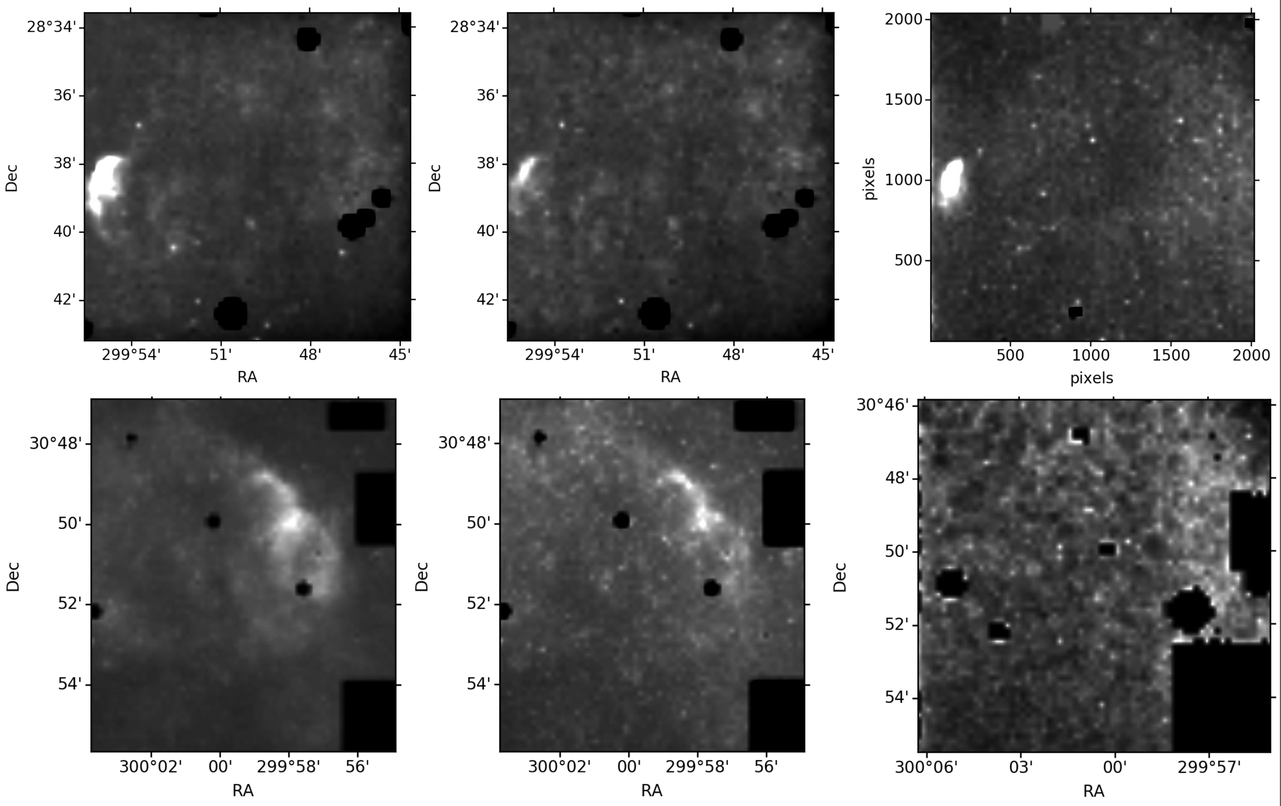

Fig. 2: Continuum Subtracted Images. The continuum subtracted images of the G65.8-0.5 (top) and G67.8+0.5 (bottom) SNR in the H_α (left), $[S_{II}]$ (middle) and $[O_{III}]$ (right) lines

Results

We demonstrated this method on 2 SNRs [Sabin et. al. 2013] (Tab. 1). Our results are presented in the Table and Figures below:

Remnant	Filter	AB Magnitude
G65.8-0.5	$H\alpha+[N_{II}]$	10.868±0.075
	$[S_{II}]$	11.10±0.11
	$[O_{III}]$	12.36±0.20
G67.8+0.5	$H\alpha+[N_{II}]$	10.015±0.021
	$[S_{II}]$	10.469±0.055
	$[O_{III}]$	11.124±0.086

Tab. 1: Narrow-band Photometry of the SNRs. After we binned-down our images to bins of 30x30 pixels, we performed aperture photometry, including to the source aperture the bins with Hα emission greater than 1σ of the background.

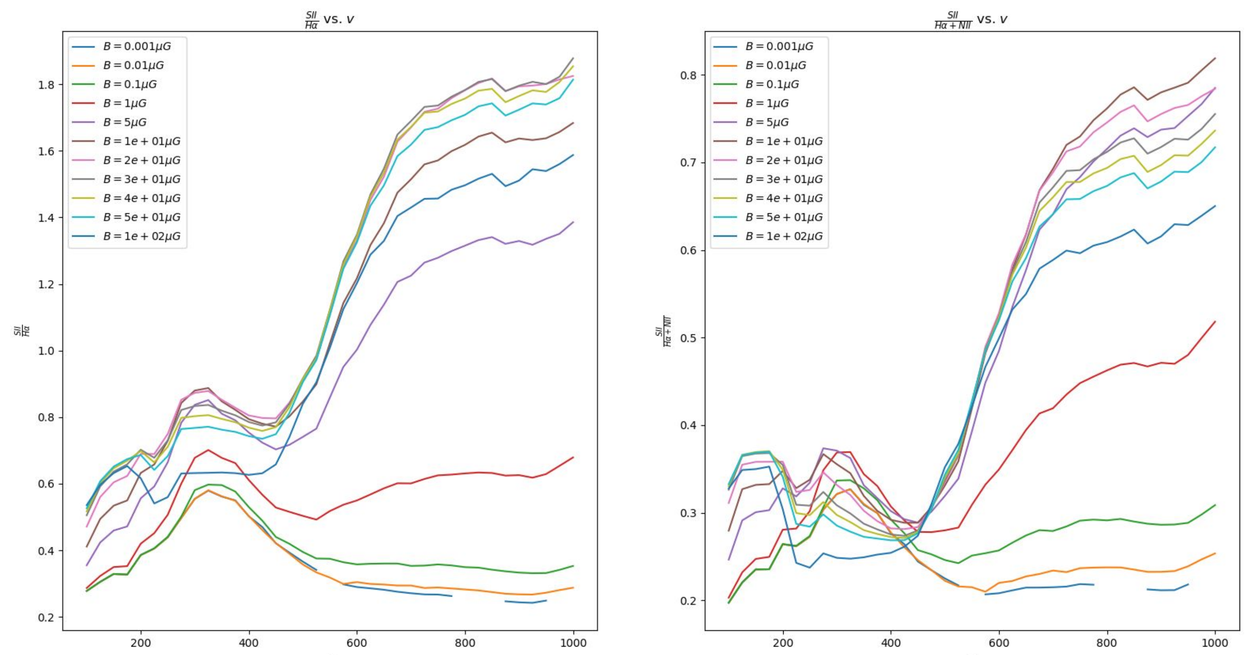

Fig. 3: New shock-wave velocity line-ratio diagnostic. The original $[S_{II}]/H_\alpha$ vs velocity relation (left), was not applicable in our methodology, due to the contamination of the H_α image by $[N_{II}]$ emission. We redefined this diagnostic using the models of [Allen et. al. 2008] to calculate the $[S_{II}]/(H_\alpha+[N_{II}])$ vs. velocity relation (middle).

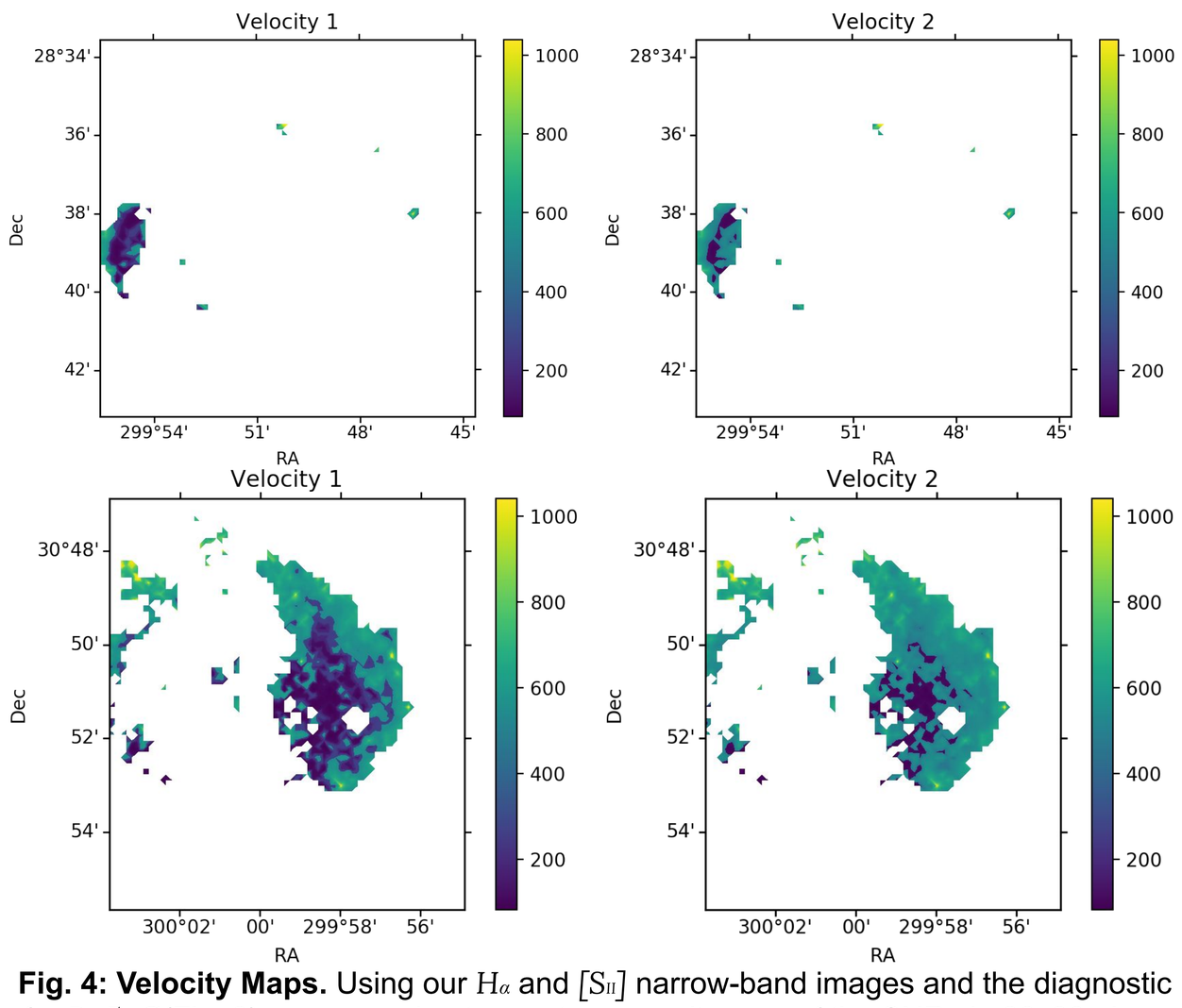

Fig. 4: Velocity Maps. Using our H_α and $[S_{II}]$ narrow-band images and the diagnostic for $B{=}5\mu G$(Fig. 3), we were able to create a velocity map of the SNRs in 30x30 pixel bins and measure the spatial distribution of velocities in the SNR. The minimum (Velocity 1) and maximum (Velocity 2) solutions are displayed for G65.8-0.5 (top) and G67.8+0.5 (bottom) remnants. This also allows us to calculate uncertainties in velocity based on the propagation of photometric uncertainties through the (non-linear) $[S_{II}]/(H_\alpha+[N_{II}])$ vs. velocity relation.

References

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